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Population dynamics of exploited species west shrimps *Parapenaeopsis coromandelica* H.Milne. Edwards 1837 from the Teluk Penyu coastal waters, Indonesian ocean

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ABSTRACT

Fishing pressure on west shrimps (*Parapenaeus coromandelica*) has increased recently and presumed to be overfished. The research aimed to study the growth, mortality and recruitment pattern of an exploited west shrimp *P. coromandelica*. The study was conducted in Teluk Penyu, the southern coastal waters of Java, Indonesia from September 2012 to August 2013. Parameters of growth and mortality were estimated by using carapace length frequency data. ELEFAN I software in the package FISAT II program was used to analyze the data. The results showed that the growth pattern of female and male shrimp were allometrical negative. Estimates of von Bertalanffy growth equation to the carapace length–frequency data gave the following results: L_∞ = 65.1 mm, K = 1.18 year^{-1} and the time of zero length (t_o) = −0.028 years for female, and L_∞ = 54.6 mm; K = 1.16 year^{-1} and the time of zero length (t_o) = −0.013 years for male. Total mortality (Z) of female shrimp was 3.87 year^{-1}, the rate of natural mortality (M) was 1,77 year^{-1} and the fishing mortality (F) was 2.1 year^{-1}. While total mortality of male shrimp was 4.23 year^{-1}, natural mortality was 2.34 year^{-1}, and fishing mortality was 1.88 year^{-1}. The rate of exploitation (E) in female and male shrimps were 0.6 and 0.58 year^{-1}, respectively. This indicated that the rate of exploitation of *P. coromandelica* have to exceed the maximum sustainable yield (E = 0.5). Time recruitment occurred between May and August, with peak recruitment in August.

Introduction

Shrimp is commercially one of the most important marine resources in the world. About 58% of the global fishery exports is shrimp products from Asia countries (Mahmood et al., 2005; Portley, 2016). In Indonesia, shrimps contribute the largest foreign exchange earnings valued at about US$ 1706 million in 2014 (Central Bureau of Statistics, 2015).

P. coromandelica is a genera of marine crustacean which are often referred to as penaeid shrimp is known as 'Udang Barat (west shrimp)' among the local inhabitants of the coastal settlement. Type of penaeid shrimp life cycle is in the estuarine and oceanic environments to complete their life cycle (Mosha and Gallardo, 2013; Macia, 2004). Beginning with female adults spawn in the ocean, then they enter to coastal and estuarine waters after reach at juvenile stage and migrate to offshore waters for further growth and development, then they migrate back to the sea for maturation and breeding (Manzano-Sarabia et al., 2007). In Teluk Penyu, west shrimps catches by indigenous gears such as traps, push nets, beach seines and set nets which operate in the brown sandy inshore regions. These equipments are being increasingly employed along the southern Java coast. As a result, a lot of small fish and shrimps catched in this area. This situation caused a serious threat to the sustainable stock of *P. coromandelica*. Previous studies reported that overfishing of shrimps in the coastal waters affected inshore recruitment and offshore stock recovery. Arellano-Torres et al. (2006) reported the effects of a fishing gear on an artisanal multispecific penaeid fishery on reduction and depletion of broodstock in a coastal lagoon of Mexico. In similar, Burgos-Leon et al. (2009) reported that harvesting of prawns in the Mexico coastal lagoon greatly affected inshore recruitment and offshore stock recovery.

Understanding of some biological aspects, such as the relationships between length-weight and growth rate-mortality is essential for the shrimp management (Bayhan et al., 2005). Growth and mortality population parameters are very important as a basic

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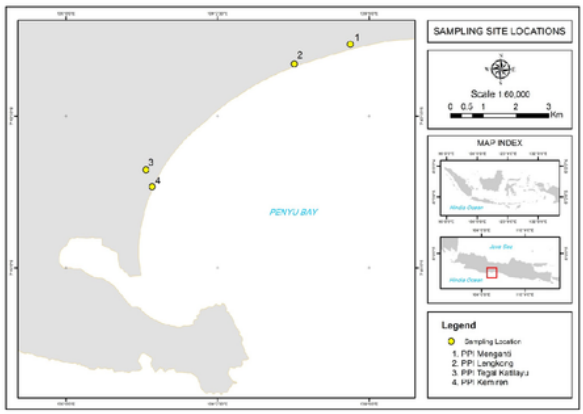

Fig. 1. Sampling site locations.

estimation for stock assessment and management (Kevrekidis and Thessalou-Legaki, 2011). Moreover, intense exploitation has resulted in a severe reduction in catches in most countries. While Montgomery et al. (2012) stated that estimates of rates of mortality (fishing and natural) are important to stock assessments and to the effective management of fish resources.

P. coromandelica is an important resource for all fisheries in the Teluk Penyu; however, the population biology and dynamics of shrimps in Indonesia have not been examined. The only information available comes from mantis shrimps collected from mudflat Sumatera island (Wardiatno and Mashar, 2011). This study aimed to determine the population dynamics of *P. coromandelica*, covering the length-weight relationship, mortality rate (total, natural and fishing), growth pattern, recruitment pattern and the level of exploitation. The results of this research can be used to develop a management model for sustainable *P. coromandelica* shrimp and sustainability efforts.

Material and methods

This study was conducted in Teluk Penyu beach, southern Java coastal waters, Indonesia. Survey method was used in this study. Sampling locations were fish landing base (PPI) of Tegal Katilayu, Kemiren, Lengkong and PPI Menganti (Fig. 1). These sampling locations were selected as study areas because they are landing sites where the shrimps. Monthly samples of *P. coromandelica* specimens were collected between September 2012 and August 2013. Samples were taken directly as much as 10% of the total catch. Samples were transported in ice boxes to the Marine Science laboratory, Semarang. In the laboratory, the samples were sexed, carapace lengths (mm) and weights (grams) measured. Linear dimensions were measured using a pair of sliding calipers with a precision of 0.1 mm. Ponderal measurements were taken using electronic weighing balance with a precision of 0.01 g. Data were analyzed for the length-weight relationship using the power function which took the form $W = aL^b$. The equation can be changed in linear form to be the formula: Log W = Log a + b Log L (Lagler, 1961; Le Cren, 1951).

Growth pattern was parameterized using the von Bertalanffy (1938) model. Length of the shrimp at first capture, the point of change of growth, mortality rate, and the rate of exploitation were also determined. Length determination of the first capture were done by using a standard logistic curve method. Calculation of the growth parameters was carried out by using ELEFAN I tool contained in the program package FISAT (FAO-ICLARM Stock Assessment Tool) II. Bilgin et al. (2009) stated that ELEFAN software was more appropriate method for estimating growth parameters of shrimp because of the short live of shrimp. The initial value of L_∞ was required for this method. The theoretical age at the time of carapace length of zero (t_o) was estimated by using the Pauly formula (Pauly, 1984). While the shrimp mortality was calculated by using the methods of length-converted catch curve. The formula of changes point growth rate (ttp) = (1/K) * ln b + to.

Results

Size structure of shrimp caught by Danish seine

P. coromandelica shrimps caught by Danish seines in Teluk Penyu waters had carapace lengths that ranged from 20 to 60 mm. Table 1, Table 2 and Fig. 2 show that the mode in the carapace length frequency of the females was 40 mm, while that for the males shrimp was 36 mm. Additionally, the mean size of female shrimp was larger than that of male.

Table 1
The length frequency data of *P. coromandelica* (female) obtained during the period of study.

Carapace length (mm)	22-Sep 2012	20 Oct 2012	10-Nov 2012	15 Des 2012	12 Jan 2013	16 Feb 2013	16 Mar 2013	20 April 2013	Total
20	0	0	1	0	–	0	0	1	2
22	0	2	1	1	–	2	1	15	22
24	0	1	2	2	–	2	5	38	50
26	0	5	4	8	1	9	6	54	87
28	0	7	2	4	1	3	4	19	40
30	2	31	41	67	7	22	10	8	188
32	0	19	23	24	3	33	27	49	178
34	0	17	9	18	4	25	35	22	130
36	17	54	59	102	25	58	47	19	381
38	0	39	17	27	19	30	28	4	164
40	12	71	105	137	27	77	53	0	482
42	9	23	20	32	18	81	65	0	248
44	14	18	17	15	24	34	31	0	153
46	14	21	62	62	43	64	44	1	311
48	9	8	11	9	16	18	19	0	90
50	24	10	20	13	4	43	31	0	145
52	4	2	4	1	–	21	9	0	41
54	2	0	2	1	1	10	9	0	25
56	6	2	4	1	4	3	2	0	22
58	5	0	0	1	–	0	1	0	7
60	5	0	1	2	–	0	0	0	8
62	1	0	0	0	–	0	0	0	1
Total	124	330	405	527	197	535	427	230	2775

Table 2
The length frequency data of *P. coromandelica* (male) obtained during the period of study.

Carapace length (mm)	22-Sep 2012	20 oct 2012	10-Nov 2012	15 Des 2012	12 Jan 2013	16 Feb 2013	16 Mar 2013	20 April 2013	Total
20	1	0	5	0	0	2	1	0	9
22	0	1	0	1	0	0	0	24	26
24	0	1	1	1	0	0	0	44	47
26	0	3	23	19	3	21	6	81	156
28	0	5	4	10	5	10	20	31	85
30	1	22	53	58	7	50	19	17	227
32	0	30	17	40	19	92	78	14	290
34	0	40	7	21	19	80	68	6	241
36	10	70	61	110	85	114	122	4	576
38	3	40	5	17	57	41	39	0	202
40	45	43	34	33	38	73	61	0	327
42	1	13	1	3	3	22	14	0	57
44	0	5	0	2	1	3	7	0	18
46	21	8	2	3	2	5	2	0	43
48	0	0	0	0	0	0	0	0	0
50	0	1	0	1	0	0	0	0	2
52	1	0	0	0	0	1	0	0	2
Total	83	282	213	319	239	514	437	221	2308

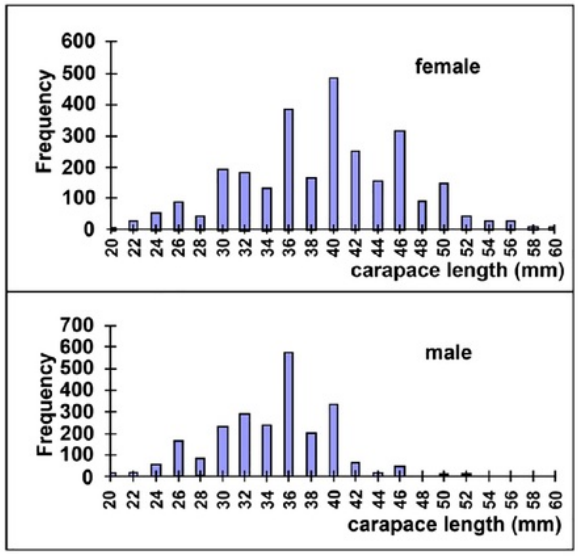

Fig. 2. Structure of the carapace length of *P. coromandelica* caught in Teluk Penyu.

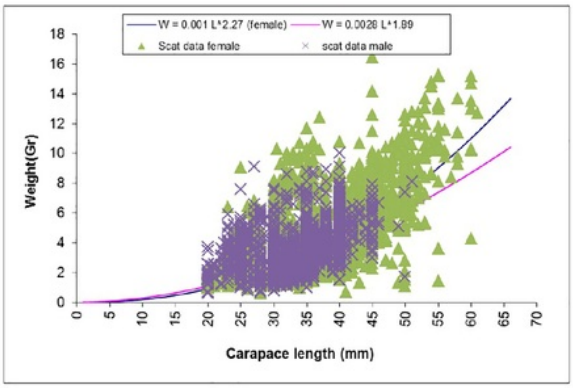

Fig. 3. Carapace length (mm) – weight (g) relationship of *P. coromandelica*.

Length-weight relationship

The length-weight relationship took the form $W = 0.000985\ CL^{2.28}$ (female) and $W = 0.0038\ CL^{1.89}$ (male). The b values of female and male were 2.28 and 1.89, respectively. These values were below 3. Although a statistical test of significance was not conducted, it is assumed that the growth of *P. coromandelica* shrimp was negative allomatric x, the weight growth was not as fast as the long growth of the shrimps. The results of weight-length relationships are presented in Fig. 3.

Carapace length of first capture of P. coromandelica ($L_{c50\%}$)

The analysis of carapace length of males and females showed that the size at first capture (L50%) for female and male were 38.3 mm 34.2 mm respectively (Fig. 4). At carapace length 38.3 mm (female), the shrimp weight was 3.98 g, while at carapace length 34.2 mm (male), the shrimp weight was 3 g. This showed that the shrimp caught by Danish seine, was dominated by small or young shrimps. The total length of the largest shrimp in the samples was 125 mm. Chan (1998) stated that *P. coromandelica* females could reach 230 mm in total length, eventhough the length size generally was less than 170 mm.

Growth parameters

Infinity length ($L\infty$) and growth coefficient curve (K)

Bilgin et al. (2009) stated that ELEFAN software was a more appropriate method for estimating growth parameters of shrimp because of the short live of shrimp. The initial value of $L\infty$ was required for this method. The values of $L\infty = 54.6$ mm, $K = 1.26$/year for male were obtained. While the female values were $L\infty = 65.08$ mm, $K = 1.1$/years. These results showed that female shrimp were generally larger than that of male shrimp.

Von Bertalanffy equation

The L_∞ and K values that have been obtained were entered to the formula resulted in the values of $t_o = -0.013$ years for the male and $t_o = -0.028$ for female. The von Bertalanffy growth equation of *P. coromandelica* were:

$$Lt = 54.6\ \left(1 - e^{-1.24[t+0.013]}\right) \quad \text{(male)}$$

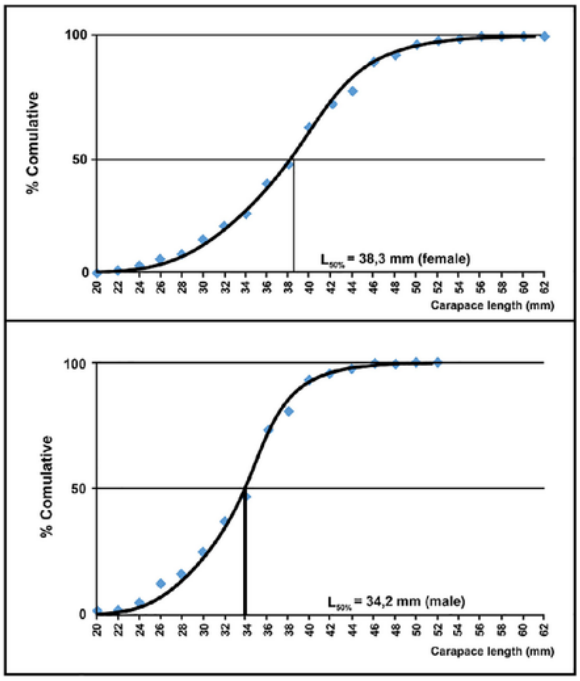

Fig. 4. Carapace length (mm) of the first capture ($L_{50\%}$) *P. coromandelica* in Teluk Penyu.

$$Lt = 65.08\ (1 - e^{-1.1.1[t+0.028]}) \quad \text{(female)}.$$

Based on von Bertalanffy equation, the growth curve could be constructed (Fig. 5).

Changes point growth rate (t_{tp})

Changes point growth values of *P. coromandelica* was 0.578 years for female and 0.664 years for male. Similarly, when the length of the carapaces were 31.66 mm (female) and 31.02 mm (male), the growth change occurred. This value indicated that after reaching a length of 31 mm, the growth of *P. coromandelica* shrimp was slowly. The mode values (36 mm for the male and 40 mm for female) were greater than that of the change of growth value.

Recruitment pattern

The results showed that shrimp recruitment of *P. coromandelica* almost occurred throughout the year, with peak recruitment occurring in March-May and August-September (Fig. 6).

The rate of total mortality (Z), natural (M) and fishing mortality (F)

Total mortality was assessed by using length-converted catch curve through ELEFAN program. The values of L_∞ = 54.6 mm, K = 1.24 year^{-1}, t_o = −0.013 years and L_∞ = 65.08 mm, K = 1.1 year^{-1}, t_o = −0.028 years were used to calculate total mortality variable of male and female shrimps, respectively. Based on those calculations, the total mortality (Z) of male was 4.23 year^{-1} (CI: 2.83 to 5.63; male), natural mortality (M) was obtained = 1.77 year^{-1} and fishing mortality (F) was 2.46 year^{-1}. While for female shrimp, a total mortality was 3.87 year^{-1}, (CI 3.24 to 4.49), natural mortality was 1.56 year^{-1} and fishing mortality was 2.31 year^{-1}.

Exploitation rate

The rate of exploitation was obtained by the equation E = F/Z. F is the fishing mortality, and Z is the total mortality (F + M). Based on the calculations, E for male shrimp was 0.58 year^{-1}, while the female shrimp was 0.6 year^{-1}. For the shrimp resource conservation, E value should be optimum. According to Gulland (1983) E_{opt} = 0.5 = $F_{opt}/(F_{opt} + M)$, in such conditions will result a sustainable catch (MSY: maximum sustainable yield). The results showed that the exploitation level of the shrimp *P. coromandelica* has been over exploitation (>0.5 year^{-1}).

Discussion

P. coromandelica shrimp growth was negative allomatric, where b value was <3. It means that the weight gain was not as fast as the increase of length. Based on the relationship curve carapace length and the individual weight, the growth of small shrimp was moderately fast at the earlier age, while weight gain was slow. On the contrary, the growth of large shrimp in this study slowed, while

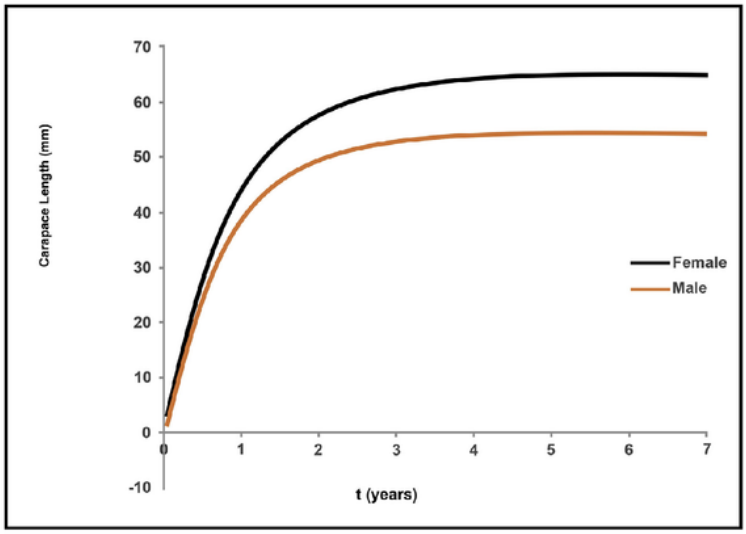

Fig. 5. The growth curve of *P. coromandelica* in Teluk Penyu Cilacap Indonesia.

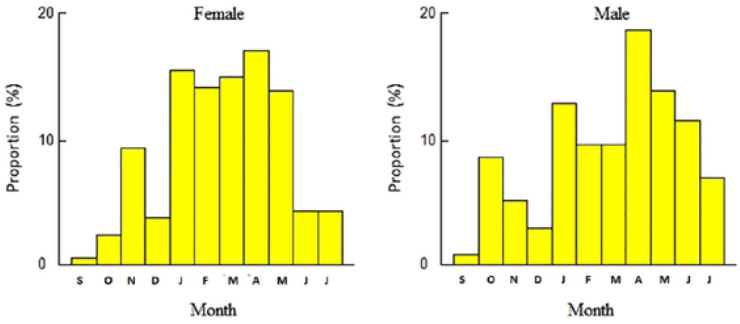

Fig. 6. The recruitment pattern of *P. coromandelica* in Teluk Penyu Cilacap, Indonesia.

the weight gain increased moderately fast. The decline point of growth rate occurred at 31.66 mm carapace length for female and 31.0 mm for male. Previous studies on various species of shrimps in tropical and subtropical waters showed that female shrimp grew faster than that of male, unless the species *P. semisulcatus* in Manila (Ye et al., 2003; Franco et al., 2006).

Value of K shrimp *P. coromandelica* was 1.26 for male and 1.1 for female. Enin et al. (1996) reported that K value on *Nematopalaemon hustatus* was 0.62. While Cha et al. (2002) reported the K values on *P. chinensis* in Korea were 0.45 for males and 0.96 for females. Moreover, Ragonese and Bianchini (1996) reported that the K value on *Aristeus antennatus* in the Strait of Sicily (Mediterranean Sea) was K = 0.74. Comparing to those study, the K value of *P. coromandelica* in this study was the highest one. However, the K values of this study were lower than that of K value on *Melicertus kerathurus* (Kevrekidis and Thessalou-Legaki, 2011), the shrimp *P. semisulcatus* (Ye et al., 2003) and *Litopenaeus stylirostris* (Martinez and Quiroz, 2005). K value describes the time required to achieve L_{∞}. The higher the value of K, the faster the growth of shrimp *P. coromandelica*. So far there has been no research on population parameters in *P. coromandelica* shrimp. However, the study on the same genera was carried out on *Parapenaeus longirostris* shrimp in Saros Bay, Aegean Sea, scored K 1.05/year for females, and 1.49 $year^{-1}$ for males (Bilgin et al., 2009).

The recruitment season of shrimp *P. coromandelica* in Teluk Penyu, Cilacap waters ranged between March to May for female and August to September for male. Mohammed (1995) reported that the recruitment of shrimp *M. affinis* in the Kuwait waters occurred two seasons, between February to May and September to October for male. while the female shrimp recruitment season occurred in March to June and July to August. Martinez and Quiroz (2005) also reported that a recruitment pattern on *Litopenaeus stylirostris* in the Gulf of California, Mexico was from March to October, with maximum recruitment from May to July. In general, penaeid shrimp have double recruit, meaning that in one year happened two seasons of recruitment. However, Etim and Sankare (1998) reported that a recruitment pattern on the fresh-water shrimp, Macrobrachium völlenhovenii in the Côte d'Ivoire, West Africa was one recruitment peak from September to November.

Total mortality (Z) of *P. coromandelica* in Penyu Bay waters Cilacap is 3.87 $year^{-1}$ (female) and 4.23 $year^{-1}$ (male). Kevrekidis and Thessalou-Legaki (2011) reported that the Z values on *Melicertus kerathurus* ranged from 1.64 to 3.98 $year^{-1}$ for females and 1.83 to 5.19 $year^{-1}$ for males. While Gerami et al. (2012) reported that the total mortality of *Metapenaeus affinis* was 4.04 $year^{-1}$ for males and 4.93 $year^{-1}$ for female shrimp. In general, mortality due to natural causes (M) and caught causes (F). The natural mortality of *P. coromandelica* in Teluk Penyu was 1.77 $year^{-1}$ (male) and 1.56 $year^{-1}$ (female). This value is relatively similar to the results of research on penaid shrimp in tropical or sub-tropical waters. Gerami et al. (2012) to get the natural mortality of *Metapenaeus affinis* was 1.96 $year^{-1}$ (males) and M = 1.75 (female). Nassir et al. (2007) reported that the instantaneous rate of natural mortality for males and females on the *Penaeus semisulcatus* 2.11 and 2.41 $year^{-1}$, respectively. The fishing mortality (F) of *P. coromandelica* gained an average was 2.46 $year^{-1}$ (male) and 2.31 (female). This value indicated that the shrimp fishery in Teluk Penyu was sufficiently developed. According to Garcia (1988), the developed fishery (catch and effort has been stable for a long period of time) were obtained when the F value is 1.6 ± 0.3 per years. In the shrimp fishery with high level exploitation, the value of F is also high. Nassir et al. (2007) found that the rates of fishing mortalities (F) of *Penaeus semisulcatus* were 4.3/year for males and 5.8/year for females in Bushehr coastal waters, Persian Gulf.

The exploitation rate (E) for female shrimp was 0.6 per year, while the male shrimp was 0.58 per year. Nassir et al. (2007) reported that the exploitation rates (E) on the shrimp *P. semisulcatus* in Bushehr coastal waters were 0.67/year and 0.7/year for males and females, respectively. It is showed that female shrimp are generally more easily to be caught than the male shrimp. This suggests that the rate of shrimp exploitation of *P. coromandelica* has been over-exploited, although not too heavy. Optimum exploitation E = 0.5 (Pauly, 1984).

Conclusions

West shrimps *P. coromandelica* were the most abundant penaeid species in the Teluk Penyu coastal waters. Our results showed that the growth of the length was faster than that of weight and growth rate of female shrimp tend to be faster than that of male shrimp. The first caught carapace length data showed that the shrimp catching was decline in the speed of total mortality *P. coromandelica*. The fishing mortality (F) of *P. coromandelica* gained was 2.46/year (male) and 2.31/year (female), indicates that the shrimp fishery in Teluk Penyu beach was sufficiently developed. Exploitation level for female shrimp was 0.6, while the male shrimp was 0.58. The findings indicated *P. coromandelica* shrimp populations were subject to growth over-exploitation.

Further research is needed on *P. coromandelica* for longer data collection time, and research on other important economical shrimp species, to get a feature of the population dynamics and exploitation status, so that a management concept can be prepared for the economically important prawns in a waters.

Conflict of interest

We, *Suradi Wijaya Saputra*, *Anhar Solichin*, *Wiwiet Teguh Taufani*, *Djuwito* and *Agus Sabdono*, as Authors declare that "there is no conflict of interests regarding the publication of this article".

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GENERAL COMMENTS

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